Micro·Hydro Power in Newfoundland and Labrador

Canada-Newfoundland Conservation and Renewable Energy Demonstration Agreement

Micro-Hydro Power in Newfoundland and Labrador

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Canada-Newfoundland
Conservation and Renewable Energy Demonstration Agreement

Our sun, wind, water and forests hold infinite energy - renewable energy - which can be harnessed for use in our industries, offices and homes. The steadily rising prices of oil and gas and the uncertainty of these fuel supplies make it profitable, even necessary, to tap our renewable resources. Yet energy savings only start here. Conservation techniques, working together with renewable energy technologies, mean further reductions in our conventional energy requirements.

Until recently, the economic and technical feasibility of many of the innovative energy techniques and technologies had not been thoroughly tested in Newfoundland and Labrador, nor in many other regions of Canada. The conditions existed for successful application of energy products and techniques. To encourage new developments and demonstrations, the federal and provincial energy departments agreed on a conservation and renewable energy agreement for each province and territory of the country.

Newfoundland's program was implemented under the **Canada - Newfoundland Conservation and Renewable Energy Demonstration Agreement (CREDA)**. The agreement, signed in June 1979, provided up to $11,250,000 over a six-year period for energy projects approved under the program. Canada's share of the costs amounted to 80 percent of the total cost and Newfoundland's share was 20 percent of the total.

The end goal of this development and demonstration program is to encourage successful application of innovative technologies. The data from these projects has been collected and information on performance and cost of the various energy systems in this province is now available.

This book presents a summary of the information available on just one of our renewable resources.

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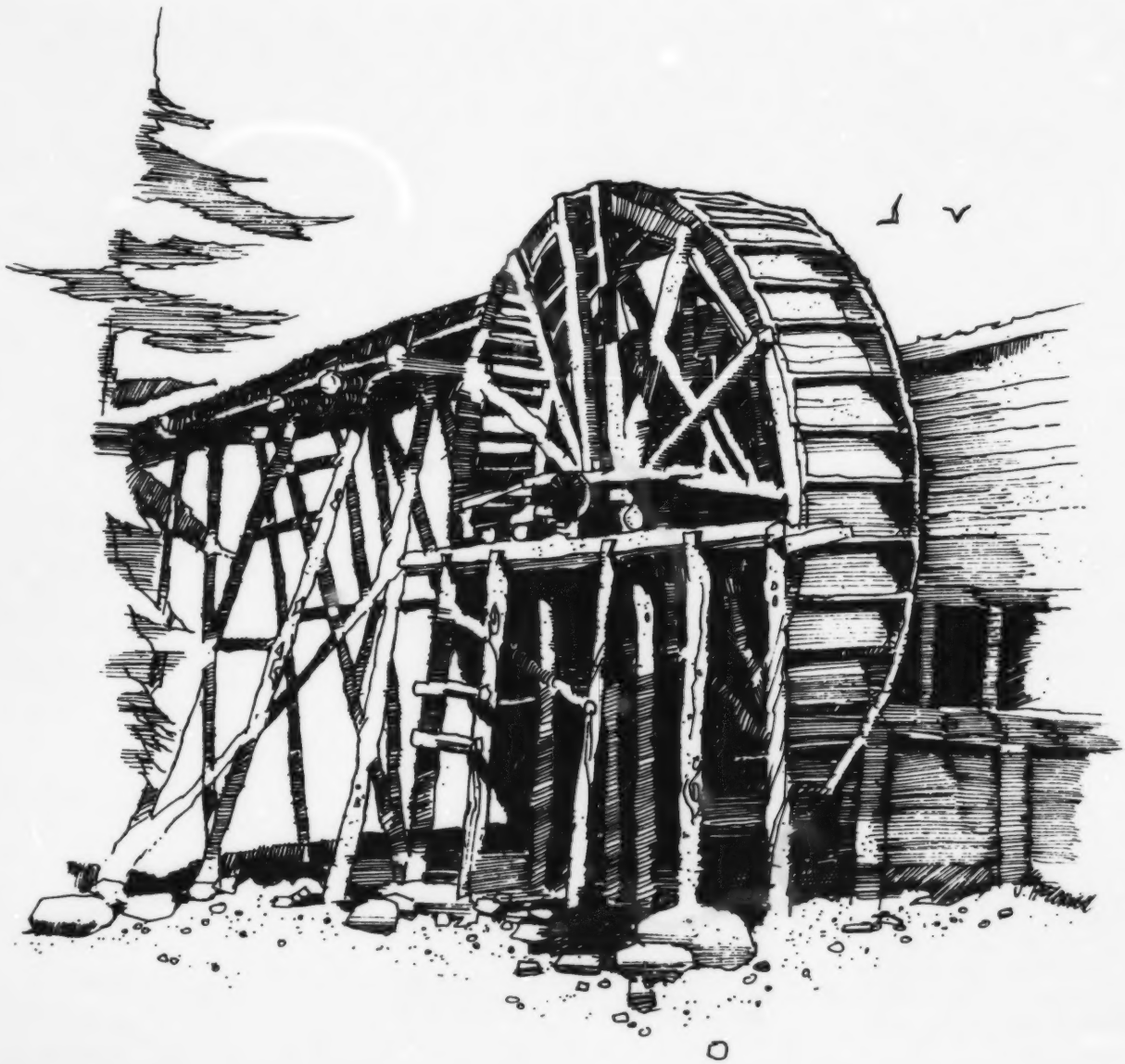
Introduction

That stream in your backyard or down the road could be a reliable source of electrical energy for you. There are hundreds of small streams in Newfoundland and Labrador that could be used to generate electricity. This book will show you how you can estimate the amount of power available from any stream and how to put that power to work to generate electricity.

Though simple in concept, micro-hydro systems can be expensive; for a 5 kilowatt system you can expect to pay as much as $15,000 before you get back a watt of electrical energy. But once in place, especially for areas where electricity from the power grid is expensive or unavailable, your micro-hydro system can provide an economical and convenient source of power.

Further information can be obtained from the references and suppliers listed at the back of this book.



Power and Energy from Falling Water

Falling water produces power by turning a wheel: the rotation of the shaft can then be used to supply either mechanical or electrical power.

Water power requires a flow of water and a waterfall, rapids or other drop, called head.

The more flow you have the less head you need, and vice versa.

Flow

Flow is simply the quantity of water passing by a point. It is measured in volume per unit time.

m^3/s (cubic metres per second)
ℓ/s (litres per second)
$1\ m^3/s = 1\,000\ \ell/s$

Typical values for Newfoundland are 0.05 m^3/s for a small brook just large enough for a few trout, 2 m^3/s for a small river such as the Waterford River in St. John's, and 80 m^3/s for a large river such as the Humber.

Head

Head is the vertical drop available to the micro hydro plant. It is convenient to have a steep drop all in one place, like a waterfall, but this is not necessary. If the drop occurs over a longer distance, as in a series of rapids, the water can be brought by a pipe from the top of the rapids to the turbine.

Calculation of Power

The flow and head are used to calculate power, using the equation

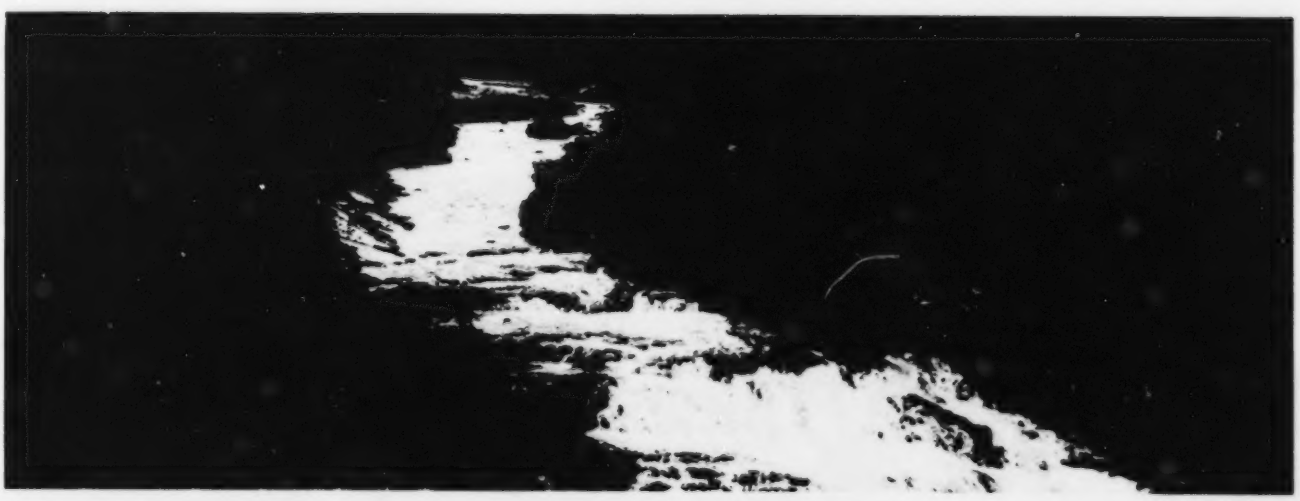
Power = 9.81
x flow
x head
x efficiency

where power is in kW, flow in m^3/s, and head in m. The efficiency is the fraction of energy converted to electricity (always less than 1) which depends on the type of equipment. 9.81 is a constant representing the specific weight of water. Note that 1 kilowatt = 1000 watts.

Estimating Power and Energy Needs

An estimate of the maximum power required at any one time and of the total energy required over a period is necessary, in order to check that a particular site can meet these requirements. It is also necessary in choosing the correct size of equipment.

An example is given below. The table on page 20 can be used to adjust this list to other situations.



An early sawmill operator took advantage of these rapids near Avondale to power a mill. A flume took the water from the small channel on the right to the waterwheel.

Estimating Energy at a Site

The most important question in planning a micro-hydro project is how much energy can be expected from the site.

To find out, the flow and head must be known. The following sections explain how to estimate these. It is not difficult but it must be done carefully.

The flow of water must be calculated or measured, not guessed. The next section "Method of Calculating Flow from Published Data" describes how to calculate it from maps and published data. "Methods of Measuring Flow in the Field" describes how to take measurements at the site.

The average annual flow and the dry month flow are both needed. The average annual flow is important in choosing equipment size. The flow in the driest month is even more important, because it will tell you how much energy you can count on.

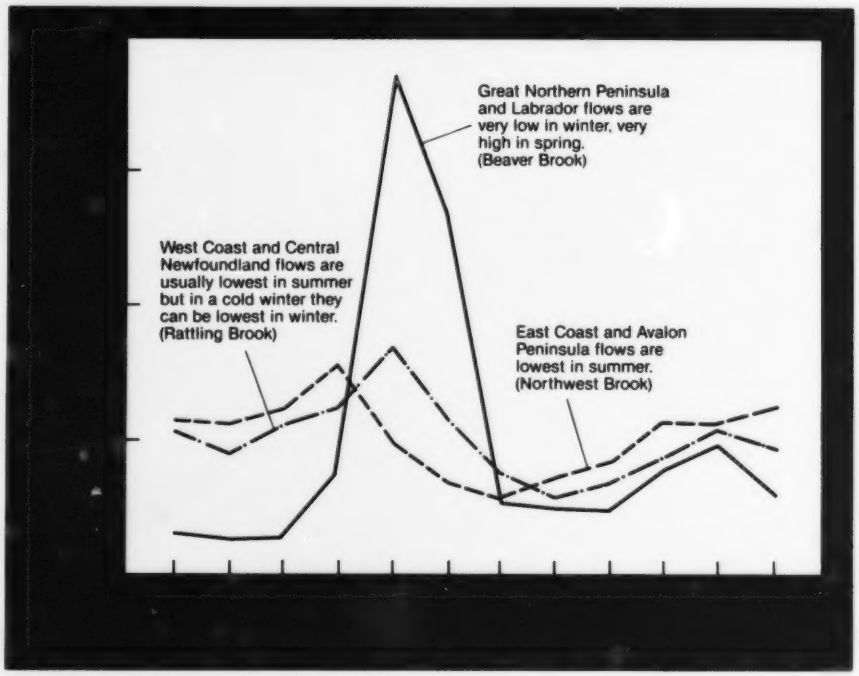
Flood flows are also required, as discussed in the section "Flood Handling System."

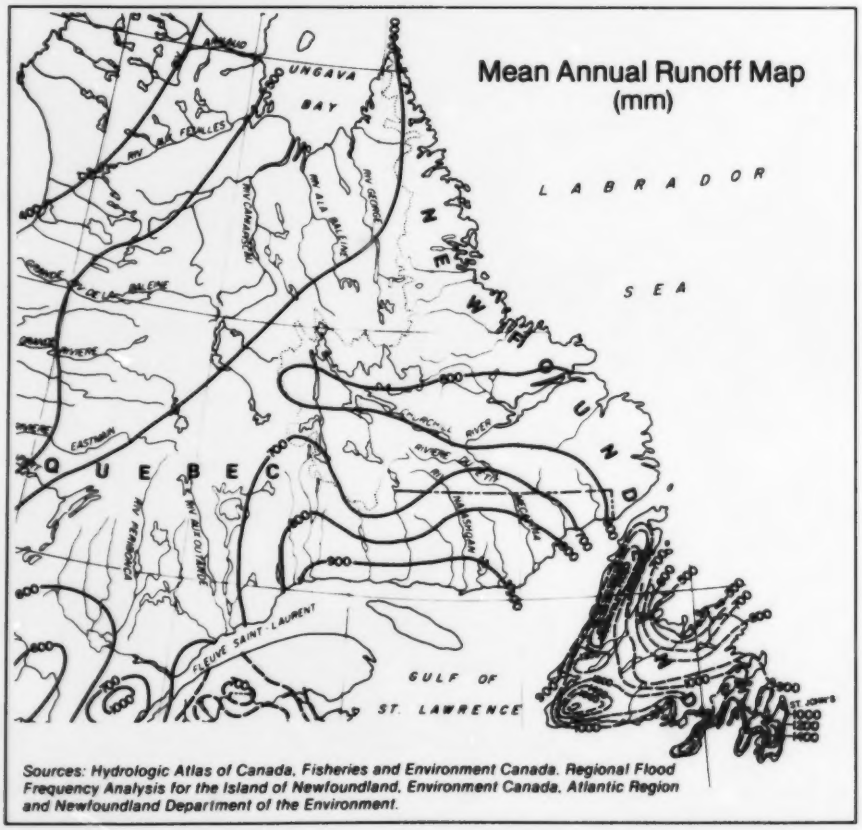
In Newfoundland and Labrador, if the winter is mild, with thaws (e.g. Avalon Peninsula, East Coast, South Coast), the driest season is the summer, i.e. June, July, and August.

If the winter is cold, with rivers frozen all winter, (e.g. Great Northern Peninsula, Labrador), the driest season is the late winter, i.e. February, March and April.

In central Newfoundland and on the west coast, the lowest flows can occur either summer or winter. In a cold winter, February flows may be lower than July flows.

The graph of flow records for some small drainage areas shows how the flow varies through the year in different parts of Newfoundland.


Great Northern Peninsula and Labrador flows are very low in winter, very high in spring. (Beaver Brook)
West Coast and Central Newfoundland flows are usually lowest in summer but in a cold winter they can be lowest in winter. (Rattling Brook)
East Coast and Avalon Peninsula flows are lowest in summer. (Northwest Brook)



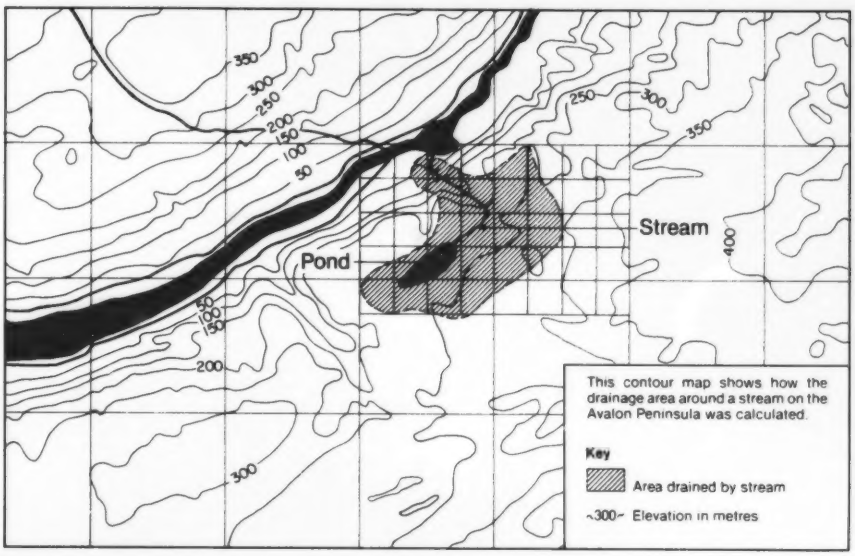
Sources: Hydrologic Atlas of Canada, Fisheries and Environment Canada. Regional Flood Frequency Analysis for the Island of Newfoundland, Environment Canada, Atlantic Region and Newfoundland Department of the Environment.

Method of Calculating Flow from Published Data

The example below shows how to use published data to calculate flow.

In addition to the runoff map on page 8, a large scale contour map showing the stream right up to its source is required.

Topographical maps may be obtained from the Provincial Department of Forest Resources and Lands, Crown Lands Division, Mapping.



Dry month flow

— To estimate the average dry month flow, use the graph of river flows. On the Avalon Peninsula, July flows are lowest, about 50% of the average annual flow. Note that these are averages; in about half the years, flows will be even lower.

Average dry month flow = 0.5 x Q

= 0.5 x 0.04 m^3/s

= 0.02 m^3/s

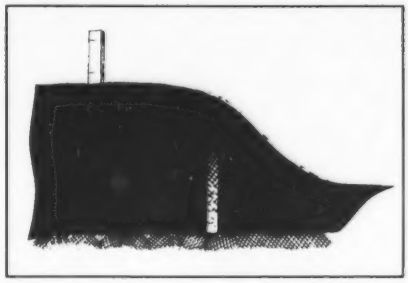
Long term flow pattern

— To get an idea of the long term flow pattern, compare the stream with a nearby gauged river. The Water Survey of Canada has long term flow records for many rivers in Newfoundland and Labrador. These records show how flows have varied over the years, and whether a particular year was dry or wet. The Water Survey of Canada is part of the Inland Waters Directorate of Environment Canada.

Methods of Measuring Flow in the Field

It is a good idea to confirm calculated flows with field measurements. Of the three common methods shown, choose one method suitable for your stream; but whatever method is used, be careful, and measure several times. Measurements can vary by plus or minus 20%, even if great care is taken.

Choose times when your stream is in a typical low flow condition to confirm calculated dry month flow. If your measurements are very different from your calculations, discuss the situation with Water Survey of Canada or provincial Water Resources personnel. They should be able to suggest reasons for the discrepancy.



Sharp-Edged Weir

Method 1. Using a Bucket

This is an easy and reliable method, but is only suitable for very small streams.

Catch all the water in the stream in a bucket with a known volume. This is easiest to do at a culvert; otherwise channel the water into a length of pipe. Measure how long it takes to fill the bucket.

e.g. 25 litres takes 10 seconds.

Flow = 2.5 litres/s

= 0.0025 m^3/s

(1000 litres = 1 m^3)

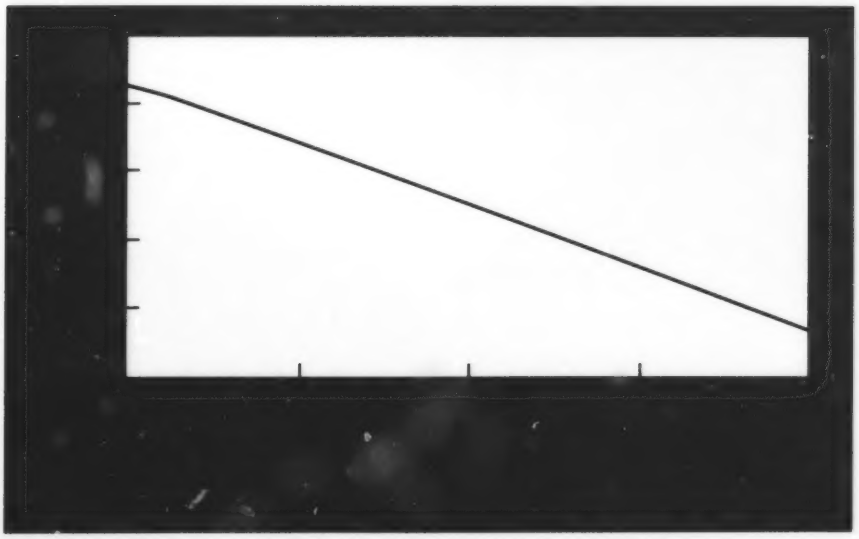
Method 2. Building a Weir

It takes work to build a weir but once built measurements are easy and accurate. The depth of water over the weir is measured. The flow can then be calculated or read from an appropriate table.

Different types of weirs require different calculations. These are given in handbooks of hydraulic engineering. For a weir of the type shown, the flow may be calculated using the following equation.

$$Q = C \times L \times \sqrt{H^3}$$

where Q is the flow in m^3/s, L is the length of the weir in metres, and H is the depth of water above the weir as measured in metres on the stake. The weir coefficient C varies with the depth of water, as shown in the graph.



Example:

Length = 1.5 m

Depth = 0.45 m

$H/L = \frac{0.45}{1.5} = 0.3$

C = 1.76 (from graph)

$Q = 1.76 \times 1.5 \times \sqrt{(0.45)^3}$

= 0.80 m^3/s

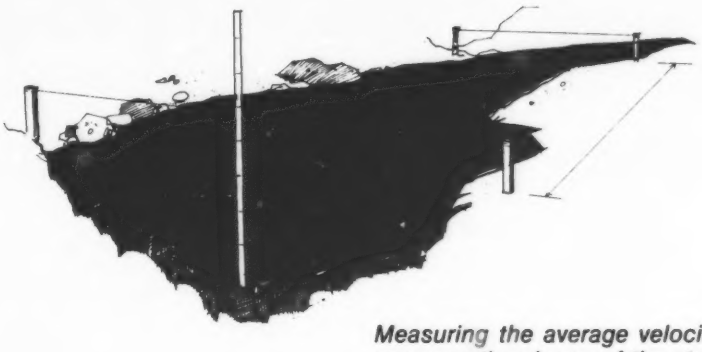
Method 3. Measuring the Average Velocity and Computing the Cross-Sectional Area of the Stream.

This method is based on the principle that

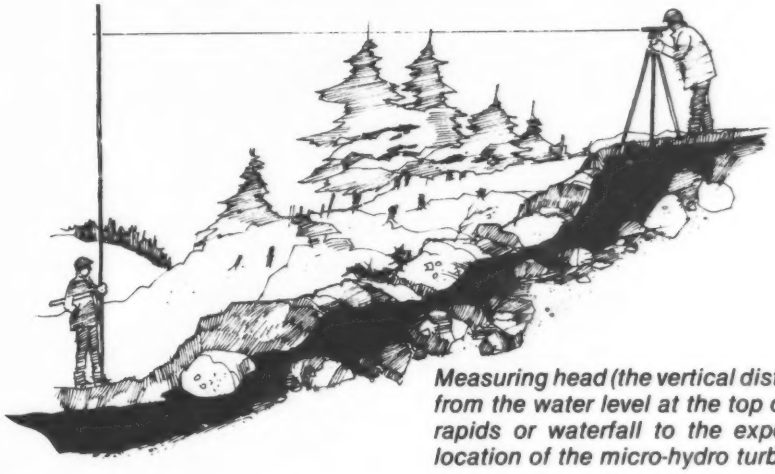
Flow Q = Average Velocity (V)
x Cross-Sectional Area (A)

The velocity can be measured either with a current meter or by floating something down the stream that will be partly submerged (like an orange or a closed empty bottle) so that it will be less affected by wind. Time it over a measured distance (e.g. 10 m) and repeat several times. The velocity on the surface is higher than the average velocity in the stream, so the measured velocity is multiplied by a factor of 0.85 to get the true average velocity. If the bottom is rough, use a factor of 0.6.

Measure the width and depth at a number of points across the stream to get the cross-sectional area.



Measuring the average velocity and cross-sectional area of the stream.



Measuring head (the vertical distance from the water level at the top of the rapids or waterfall to the expected location of the micro-hydro turbine).

Calculating Power and Energy

When the flow and head at the site are known, the power and energy can be calculated. For the example, assume a modern turbine with an efficiency of about 80% will be used. To be on the safe side, assume the other losses reduce this to an overall efficiency of 50%. Using the equation on page 6 and the average flow,

Average
Power = $9.81 \times Q_{avg} \times H \times$ Efficiency

= $9.81 \times 0.04\ m^3/s \times 15\ m \times 0.5$

= 2.9 kW

Now convert the average power to energy to find out if the required 880 kWh per month is available.

Average
Energy = Power x Time

= 2.9 kW
x 730 hours per month

= 2117 kWh per month

Check for driest month (50% of average, on the Avalon Peninsula).

Energy in
driest month = 0.5 x 2117 kWh

= 1058 kWh.

So enough energy is available to meet the average monthly requirement, even in a dry month.

Hydro Systems

The main elements of a micro-hydro system are usually
- Dam (with intake)
- Spillway
- Pipe (Penstock)
- Turbine/generator
- Powerhouse and tailrace
- Power line
- Storage/Backup

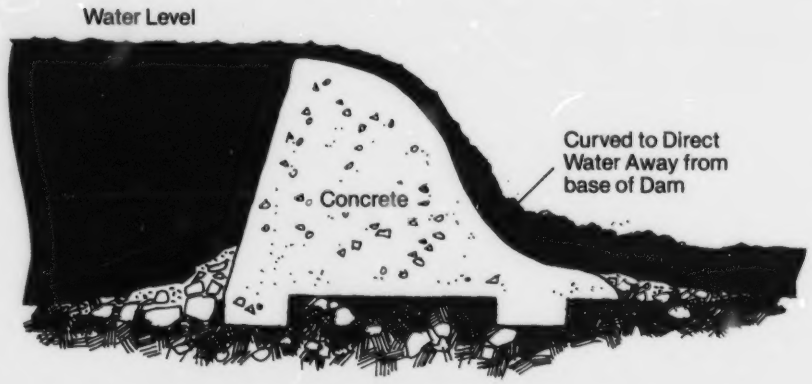
This section describes these elements.

Dam

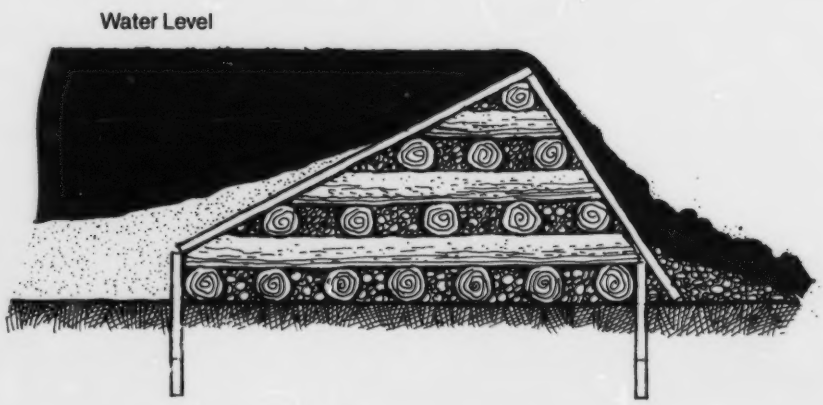
A dam is used to hold back water in order to provide an intake pond and a steadier flow of water. If the stream is quite large, the intake can sometimes be kept submerged in the stream without a dam.

When building a dam consider
- location. Look for a narrowing of the river at the top of the incline, with a pond behind it.
- material. Timber crib, rock or concrete are all suitable materials.
- foundation. Clear all vegetation to get a good seal, and make sure the soil will not erode from underneath.
- methods of leak-proofing. Treated timber sheets, concrete, or layers of impervious clay are possibilities.

Dams can be expensive, so the type of dam and its location must be carefully chosen.



Concrete Dam



Timber Crib Dam

Flood Handling System (Spillway)

Extra water must be handled during floods. If the water level rises too high in the intake pond, the dam may wash out or equipment may be damaged. Ideally, excess water should flow back to the original path of the stream.

Some types of dams are not damaged if they are overtopped, e.g. concrete or timber crib. The dam itself acts as a spillway.

To estimate how large a flood may be expected, look for high water marks, talk to long-term residents, and watch the stream in heavy rainfall and snowmelt events. It is better to have a flood handling system that is too big rather than too small.

Pipe or Flume

The water is usually brought from the intake to the turbine in a pressure pipe called the penstock. The intake must be covered with a trashrack to prevent debris and ice from entering the pipe and damaging the equipment.

The pipe must be
- as straight as possible
- always downhill
- well anchored
- protected against both freezing and hot sun by insulation or burial.

Pipe can be made of polyethylene, fibreglass, PVC, metal or rubber. Both turbine and pipe manufacturers will recommend the required size.

Open aqueducts, called flumes, are frequently used in waterwheel installations.

Turbine

The turbine is the heart of the system, because it forces the water to turn a shaft which is then used for mechanical or electrical power. There are two main types of turbines; impulse and reaction.

The type of turbine and its size depend on the particular site. Knowing the flow, head and energy needs, manufacturers will recommend the best size and type of turbine.

Most micro-hydro projects use modern turbines, but waterwheels are an alternative for those who need mechanical power only (e.g. for a sawmill) or who prefer to build their own system rather than buy a turbine.

Generator

The generator converts the mechanical energy produced by the turbine to electrical energy. Electrical energy can be direct current (DC) or alternating current (AC). Small units up to about 5 kW are often DC. Larger ones are usually AC.

The manufacturer will recommend the best unit for a given site and requirements.

A low rpm generator is required for a waterwheel, because it turns very slowly compared to a modern turbine. The rotations must be geared up to produce electricity, and the less gearing the better.

If a generator from an old lighting set can be located, it can be rehabiliated. These were in common use before the province was electrified and often ran at low rpm's.

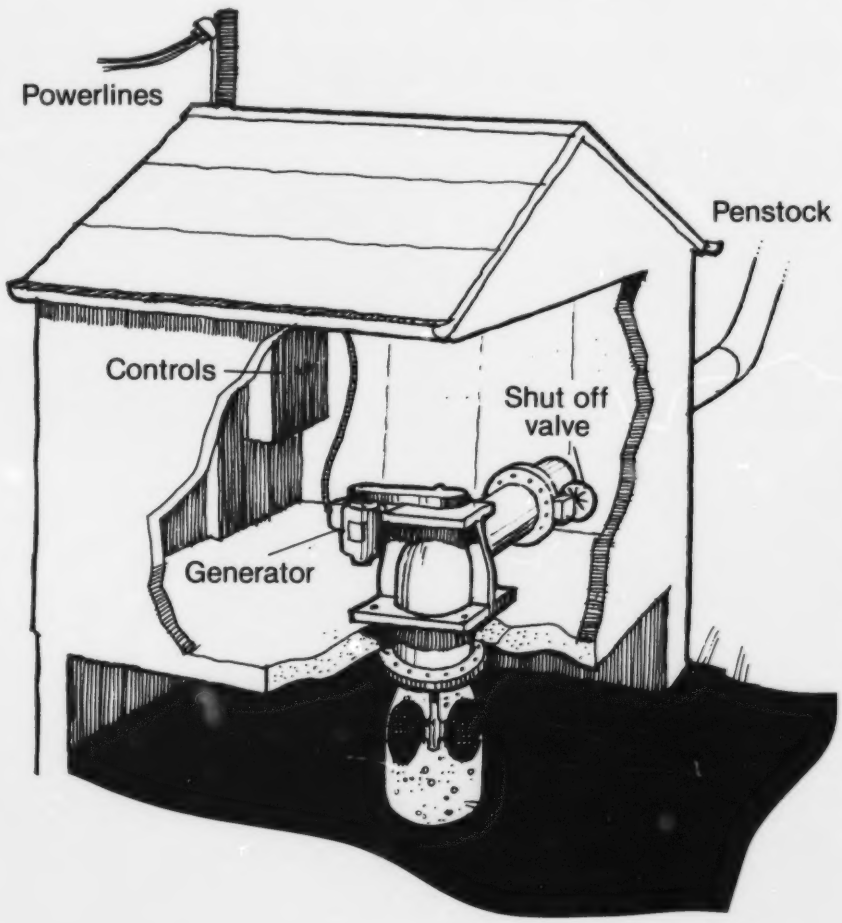
Powerhouse and Tailrace

The building housing the turbine/generator unit is called the powerhouse. It need only be a simple structure, but the foundation for the unit must be solid. The proposed powerhouse foundation should be discussed with the manufacturer before construction.

The tailrace is a simple channel (protected from erosion) which allows the water to flow back to the stream after it has passed through the turbine.

Power Line

The common way of getting the electricity from the generator to the house is on overhead lines. The turbine/generator manufacturer can advise on the required size and type of controls and cable. National and local electrical codes require certain wire sizes for given voltages and ampere loads. The system must be carefully wired by an experienced electrician, using good quality cable.



Storage/Backup

Batteries

Batteries can be used to take up surplus power and to serve as a back-up for the system. Since they store DC power, a rectifier is needed if the generator produces AC, and an inverter to convert it back again to AC for use.

Unfortunately up to 30% of the power may be lost in the inverter. An alternative is to use only DC appliances; it is possible to purchase everything from a refrigerator to a stereo in DC.

Connection to Grid

In areas served by Newfoundland Light and Power or Newfoundland Hydro another option can be considered. It is called grid connection.

The micro-hydro unit produces as much electricity as possible. Any excess not used by the homeowner is sold to the Utility. In times of low flow, when the micro-hydro plant is not producing enough power, the homeowner draws from the Utility. With this system, no battery backup is needed.

Approval must be obtained from the Utility. Check with them for their requirements.

Economics

How much will a micro-hydro system cost? This is very difficult to estimate, because it depends so much on site conditions, and on how much work the owner is prepared to do.

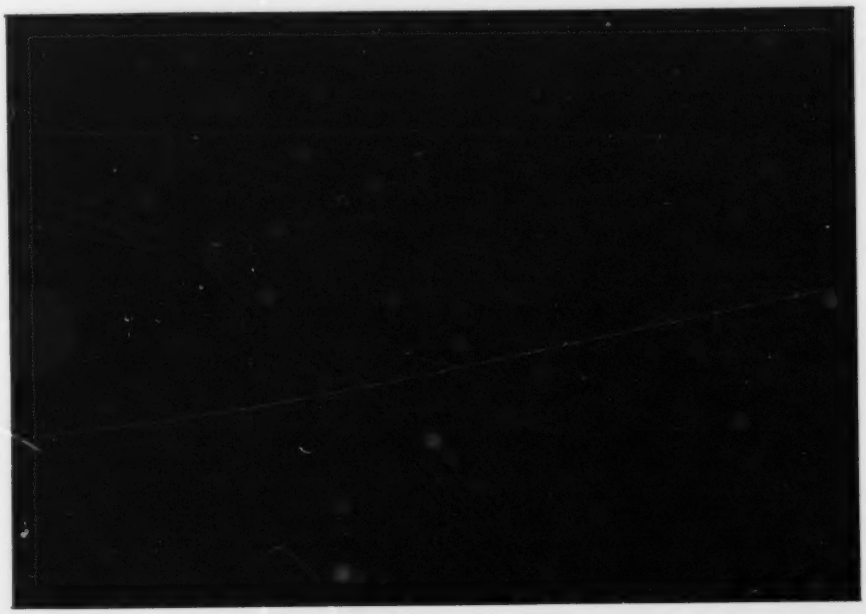
The total cost can range from less than $1000 to over $20 000 depending on the size of the system. Equipment manufacturers cannot give cost estimates without knowing the details of the applications.

High head/low flow systems will cost less than low head/high flow systems, because with low flows all parts such as pipes, turbine, dam and spillway will be smaller. If some part of the system already exists, for example a dam, the total cost will obviously be lower.

Comparing costs and savings will give what is called the payback period, i.e. how many years it will take before savings have made up for initial costs.

Three examples are given to show how the payback varies with particular cases. The energy produced in each case is
880 kWh/month = 10 560 kWh/year.

The payback period ranges from 3 years to nearly 20 years. It is clear that a careful calculation must be done for each situation.



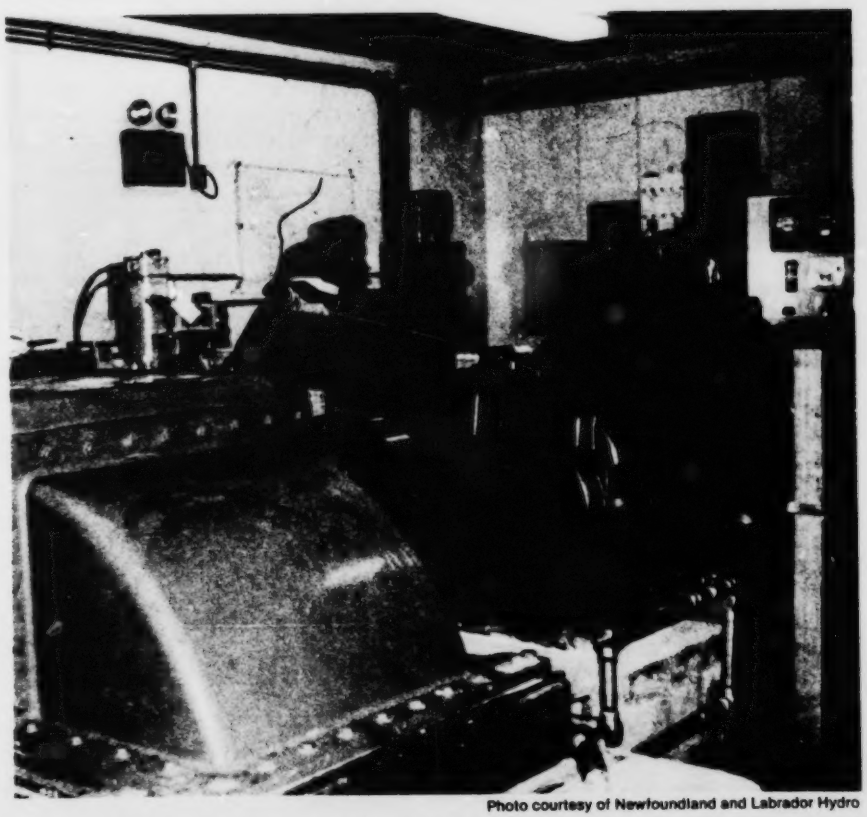


Photo courtesy of Newfoundland and Labrador Hydro

This compact mini-hydro unit at Roddickton generates an average of 1 300 000 kWh each year, saving many thousands of dollars by reducing diesel consumption.

Cautions

Harnessing hydro power is not without its problems.

— Damming streams can harm fish or plant life. The project must be approved by both federal and provincial environmental officials.

— The diversion must not affect stream flow to other users downstream.

— The equipment must be reliable. Ask the manufacturers for names of other customers and talk to them.

— The trashrack must be kept in good shape. Garbage, wood or ice in the turbine could damage equipment.

— All equipment and other parts of the system must be able to withstand the climate, including very heavy rains, hot sun, strong winds and freeze/thaw cycles.

These falls on a tributary to North Harbour River (St. Mary's Bay) are a natural barrier to trout and salmon. Care must be taken when any changes are planned to a river not to impede natural migration patterns.

Summary

Like most renewable energy projects, micro-hydro has its advantages and disadvantages. In general, the advantages are
- well-proven equipment, nearly maintenance free
- low operating cost for many years
- pollution-free energy.

The disadvantages are
- high initial cost
- persistence required to overcome initial difficulties.

With the right location, however, and enough money and patience at the start, a micro-hydro project can provide many years of reliable, free energy.

The Petty Harbour generating station has been producing electricity cheaply and reliably since the turn of the century.

Example Project

Project Name: Private Farm Micro-hydro
Gillams, Newfoundland

Project Description: This project is presently under construction (1984/85).

A brook runs through a farm which is not served by Utility lines. A head of about 55 m and a design flow of 0.017 m^3/s will produce a maximum of 6 kW of power, as presently planned. The system will easily meet the present demand of 12 000 kWh/year, and will allow expansion of the farm.

Besides the potential financial savings, the biggest advantage of the system to the owners will be the savings in human energy, and the possibility of increased production at the farm.

Costs: (1982 $)		
	Dam	$1 400
	Powerhouse	$2 400
	Fittings	$7 000
	Turbine/Generator Unit	$8 500
	Wiring	$2 000
		$21 300

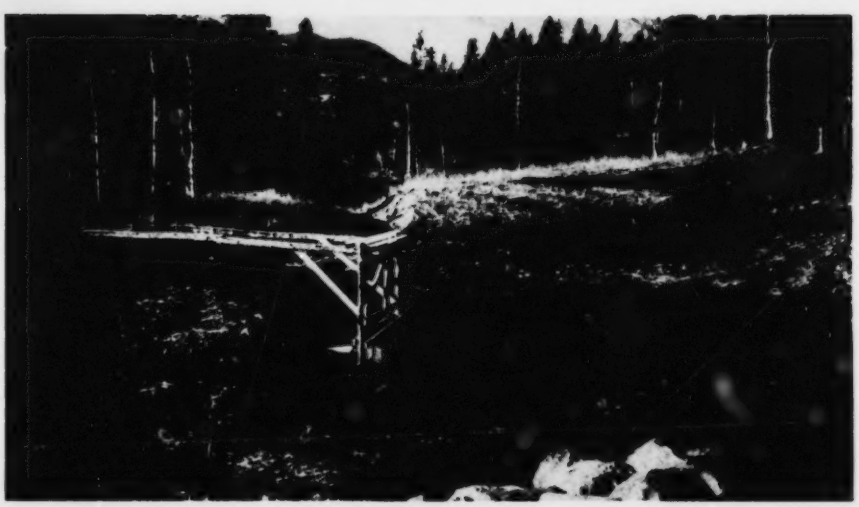
Savings: The savings depend on how rapidly the farm is expanded. Assuming 25 000 kWh of energy is used, then

Savings = 25 000 kWh @ $0.045/kWh (1982 price)

= $1 125/year

$$\text{Payback period} = \frac{\text{Costs}}{\text{Savings}}$$

$$= \frac{\$21\,300}{\$1\,125} = 18.9 \text{ yrs.}$$



Earth dykes were built to create a small intake pond for this micro-hydro project near Gillams. The pipe carrying the water to the turbine can just be seen under the wooden structure.

References

There are many excellent references on hydro energy. The books and government publications listed below are available from the library of the provincial Department of Mines and Energy. The periodicals may be obtained through libraries.

Books

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Renewable Energy Projects in Nova Scotia, Energy Mines and Resources Canada and Nova Scotia Department of Mines and Energy, 1983.

Visual Material

National Film Board of Canada.
Provincial Department of Mines and Energy.

Suppliers

Listed below are the names and addresses of manufacturers of microhydro power plants with their ranges of plant sizes.

Allis-Chalmer Canada Inc.
1 Yorkdale Place
Toronto, Ontario
M6A 3A1
Tel. 416-789-5337
Tlx. 06-969768
Size Range: 50 - 5000 kW

Barber Hydraulic Turbine
P.O. Box 340,
Barber Point, Barber Drive
Port Colborne, Ontario
L3K 5W1
Tel. 416-834-9303
Tlx. 061-5471
Size Range: 50 - 15,000 kW

Canyon Industries
5346 Mosquito Lake Road
Deming, Washington
98244, USA
Tel. 206-592-5552
Size Range: 1 kW - 1000 kW

Dominion Bridge - Sulzer Inc.
CP/P.O. Box 555
Lachine, Quebec
H8S 4E7
Tel. 514-634-3551
Size Range: 100 - 2000 kW

Flygt Canada
P.O. Box 7
St. John's, Newfoundland
A1C 5H5
Tel. 722-6717
Size Range: 20 - 500 kW

Ossberger
F.W.E. Stapenhorst Inc.
Canadian Distributor
283 Labrosse Ave.
Point Claire, Quebec
H9S 1A3
Tel. 514-695-8230
Tlx. 05-823597
Size Range: 1 - 1000 kW

Galt Energy Systems
Box 1534
Cambridge, Ontario

Gilbert Gilkes & Godron Ltd.
Heap Noseworthy Limited
Newfoundland Representative
P.O. Box 12061
St. John's, Newfoundland
A1B 4B2
Tel. 722-1470
Tlx. 016-4554
Size Range: 5 - 10,000 kW

Independent Power Company
12340 Tyler Foote Road
Nevada City, California
USA 95959
(for miniature battery-charging units)

Small Hydro Electrics
Canada Limited
P.O. Box 45
Silverton, B.C.
V0G Z8O
Tel. 604-358-2406
Tlx. 041-4150
Size Range: 2 - 1500 kW

Solace Energy Centre
2425 Main Street
Vancouver, B.C.
V5T 3E1
Tel. 604-879-5258
Size Range: 0.2 - 100 kW

Waterwheel Erectors Limited
P.O. Box 246
Welland, Ontario
L3B 5P4
Tel. 416-735-5122
Size Range: 100 - 2000 kW
(Comprehensive services for hydroelectric projects)

Worthington Canada
JC Pratt (1974 Limited)
Newfoundland Distributors
P.O. Box 8160
St. John's, Newfoundland
A1B 3N5
Tel. 722-5690
Size Range: less than 1500 kW

Typical Household Appliance Loads

(adapted from Newfoundland Light and Power, "*What's Watt*")

Kitchen	Typical Connected Load (Watts)	Average Monthly Kilowatt Hour (kWh) consumption
Dishwasher	1 200	40
Fan	75	8
Range	12 000	100
Coffee Percolator	300	3
Fry Pan	1 150	3
Kettle	1 500	11
Mixer	150	1
Toaster	1 000	3
Refrigerator — Manual Defrost	400	60
Refrigerator-Freezer — Frost-free	900	135
Chest Freezer	340	119
Laundry		
Wringer Washer	250	4
Automatic Washer	350	5
Iron	1 000	4
Dryer	5 600	90
Water Heater — Standard 30-Gallon	2 000	480
Water Heater — Cascade 40	3 000	540
Water Heater — Cascade 60	4 500	610
Comfort and Health		
Double Blanket	180	10
Supplementery Heater	1 000	50
Heating Pad	65	1
Hair Dryer	700	6
Entertainment		
Stereo	150	11
Radio	50	4
Colour Television	400	60
Black & White Television	200	30
Outdoors		
Car Block Heater	400	96
Car Warmer	750	135
Lawnmower	1 000	10
Other		
Clock	4	3
Furnace Blower	250	50
100 watt Lamp	100	9
Sewing Machine	100	1
Vacuum Cleaner	500	3
Water Pump	250	23
Well Pump	450	20